NEAR-STREAM RECHARGE AS A TOOL FOR PRESERVING BASEFLOWS ON THE UPPER SAN PEDRO RIVER
in the Sierra Vista Subwatershed of Arizona and Sonoran Subwatershed of Mexico

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People, Groundwater, and Streamflow

Storm runoff and groundwater in the Upper San Pedro Basin (USPB) sustain the north-flowing Upper San Pedro River (USPR) (Figure 1). Precipitation that filters down into the earth during wet periods is stored in an aquifer, and then flows by gravity out of the aquifer at the low point in the basin as baseflow. Baseflow is streamflow that is fed solely by groundwater, and which keeps the stream flowing even in the dry seasons (Figure 2).

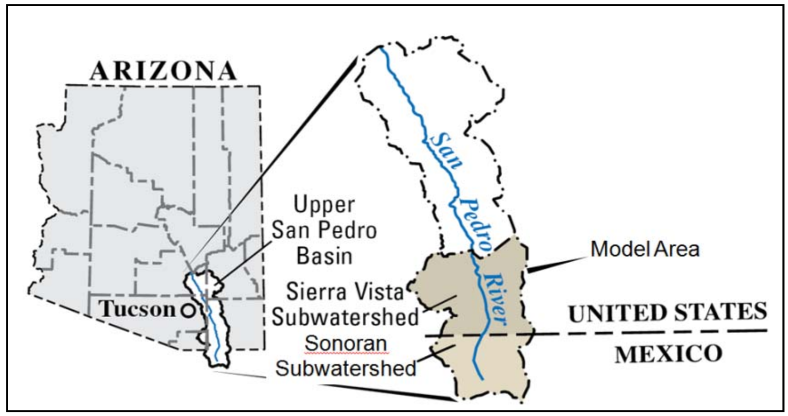

Figure 1. Location map for the Sierra Vista and Sonoran subwatersheds of the Upper San Pedro River Basin.[1]

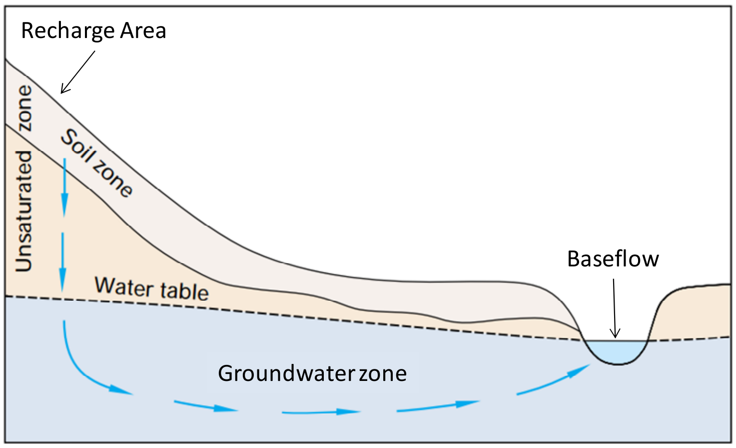

Figure 2. Schematic of groundwater recharge at mountain front and discharge as baseflow in stream.[2]

Groundwater pumped from this aquifer is also the primary source of water for most of the residents in the Sierra Vista and Sonoran subwatersheds, collectively known as the USPB. Much of the groundwater used in the USPB is lost to evaporation while some may be returned to the groundwater system through recharge. Natural groundwater consumption occurs when plant roots access groundwater, which happens primarily along streams and rivers in the USPB. Humans consume groundwater by pumping it from the aquifer and then using it for outdoor irrigation or allowing it to evaporate through other means. Water used inside homes that are connected to sewer systems eventually makes its way to treatment plants where it is cleaned before being allowed to evaporate or seep back into the ground through natural washes or man-made facilities. Examples of passive recharge include septic system drain fields and downward seepage of excess irrigation water. Active recharge efforts may include detaining urban storm runoff or discharging treated sewage effluent to earthen basins to encourage infiltration into the ground.

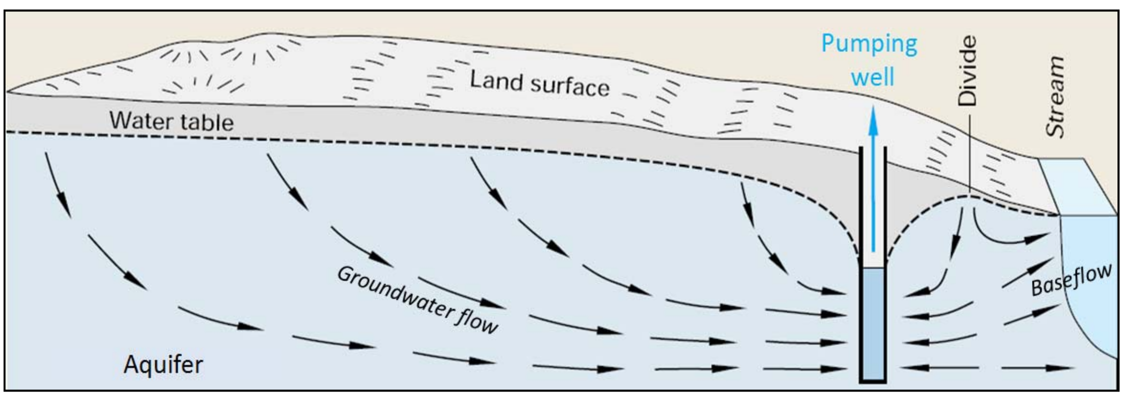

Figure 3. Groundwater flow system altered by pumping from a well. The well draws water toward it from the recharge area on the left and from the baseflow discharge area on the right, thereby reducing the amount of groundwater flowing into the stream as baseflow.[2]

People's use of groundwater from the aquifer for irrigation and other consumptive purposes diverts water that would otherwise flow in, or to, the USPR. A pumping well between a natural recharge area and a stream may: 1) capture water directly from the stream, 2) intercept recharge before it reaches the stream — thereby reducing groundwater discharge to the stream, or 3) effect some combination of stream capture and recharge interception .[1,2]

Groundwater Changes in the 20th and 21st Centuries

In 2007, the United States Geological Survey (USGS) published a computer model for simulating the response of groundwater and baseflow to groundwater pumping and recharge in the USPB.[3] This model, covering the period 1902 to 2003, reflects the fact that during the 20th century, groundwater levels in the Sierra Vista area fell by more than 100 feet as a result of intensive pumping associated with urban development. Other areas of significant groundwater decline in the USPB during the 20th century include the agricultural area near Palominas, Arizona, and the mining region near Cananea, Mexico.[3] In 2011, Lacher Hydrological Consulting (LHC) updated the USGS model and used it to project groundwater and baseflow conditions in the USPB through the end of the 21st century.[4] These projections assumed future water use patterns consistent with those in the basin today, and population growth as projected by the U.S. Census across census block groups in Cochise County.[4]

Figure 4 shows the computed groundwater declines in the primary USPB aquifer for the years 2000, 2050, and 2100. The red, orange, and yellow areas in this figure highlight the anticipated expansion of the most severe areas of groundwater depletion in the USPB between 2000 and 2100.[a] By October 2100, groundwater levels across most of the west side of the USPR in the Sierra Vista subwatershed are projected to be 60 feet or more below their pre-development levels. This projection represents an additional 40 to 50 feet of groundwater decline from the year 2000. The model predicts that groundwater levels south and west of Sierra Vista will decline by about 70 feet between 2000 and 2100, to a total depth of 170 feet below predevelopment levels.[4]

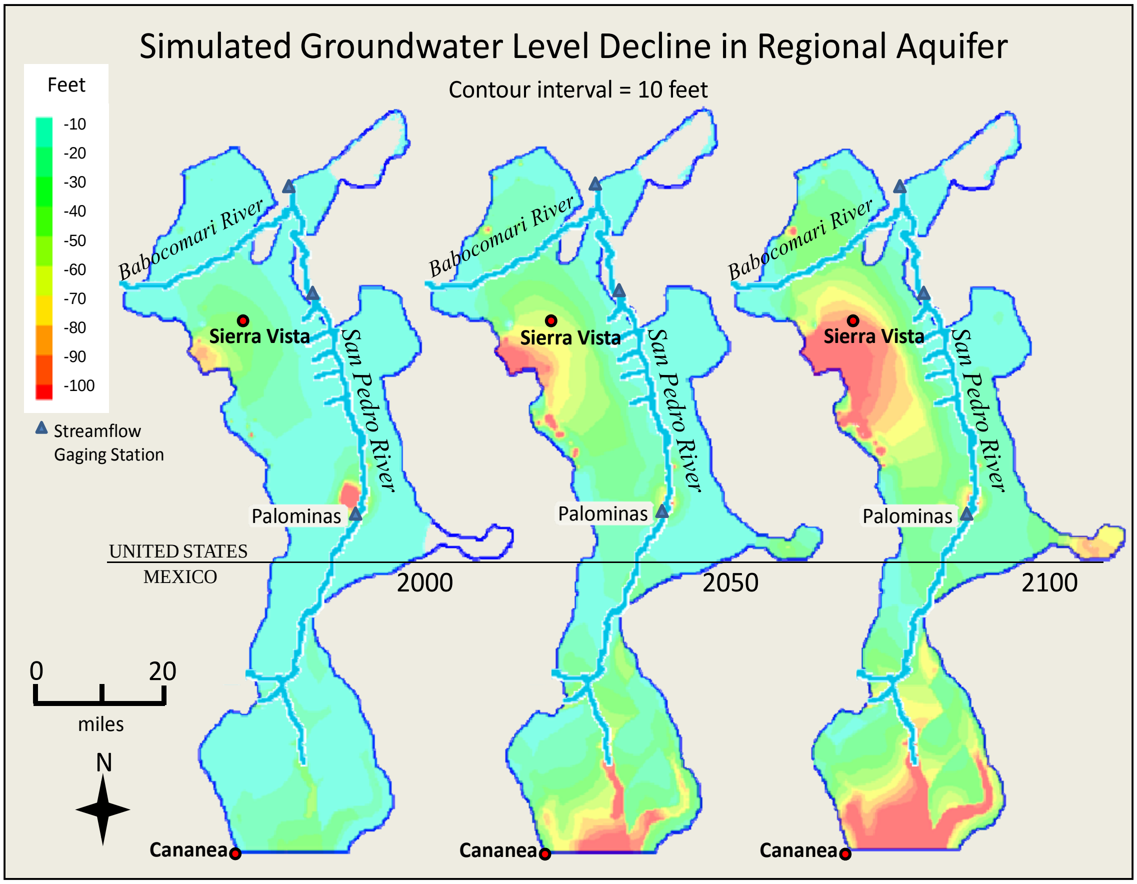

Figure 4. Simulated change in groundwater levels in the regional aquifer from pre-development time to 2000, 2050, and 2100. Warm colors (red and orange) show areas of groundwater depletion.

Baseflow Changes

Figure 5 illustrates how baseflows in the USPR and the Babocomari River are expected to change from 2000 to 2050 and from 2000 to 2100. Figure 5[a] (March 2050) shows baseflow increasing about 1 cubic foot per second (cfs) (or 23%) at Charleston from 2000 to 2050. This increase results from the groundwater mounding under the City of Sierra Vista's wastewater recharge facility (WRF). As highly treated effluent filters down through the sediments below the WRF, it raises the local groundwater elevation (Figure 6). This groundwater mound then forces some groundwater to the surface, where it flows into the river system as baseflow. Elsewhere in the basin, baseflows are expected to either remain unchanged or decline between 2000 and 2050. In particular, baseflows are predicted to drop by 35% (0.4 cfs) at Palominas and by 63% (0.9 cfs) on the lower Babocomari River between 2000 and 2050. By 2100 (Figure 5[b]), model results show baseflows declining by 83% (1.2 cfs) on the lower Babocomari and by 5% (0.2 cfs) at Charleston. Simulated baseflows at

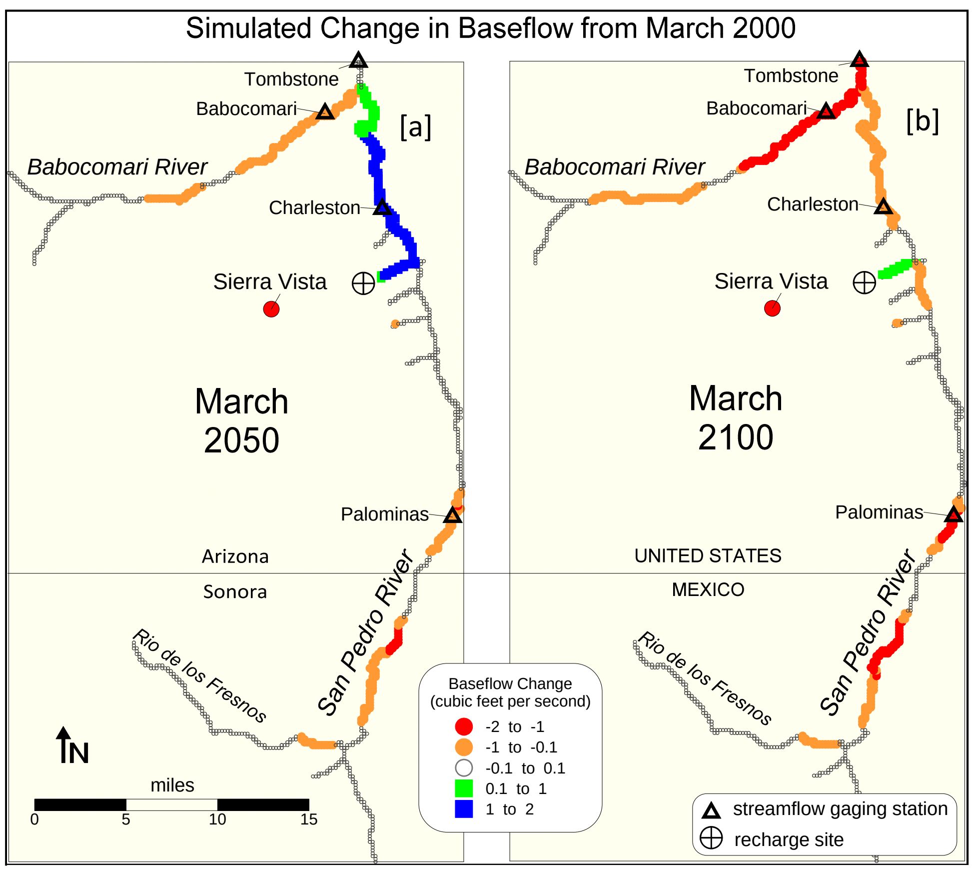

Figure 5. Simulated change in baseflow from 2000 in the San Pedro and Babocomari rivers as of [a] March 2050, and [b] March 2100, with no changes in basin-wide water management.

Tombstone and Palominas drop by 22% (1.7 cfs) and 100% (1.2 cfs), respectively, between 2000 and 2100.[4]

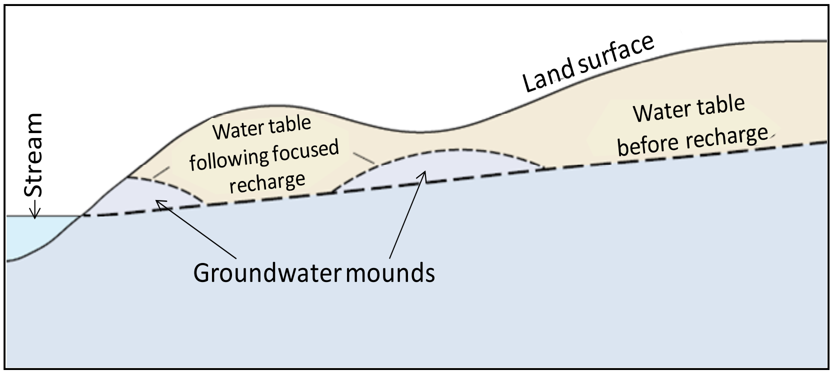

Figure 6. Schematic drawing of groundwater mounds resulting from focused recharge.[2]

What We Can Do to Preserve Baseflows

In the same way that we have observed recharge at the Sierra Vista WRF raising the groundwater level under that site and increasing baseflows downstream, strategic application of recharge at other sites near the Upper San Pedro and Babocomari rivers may help preserve baseflows in the USPR despite increased groundwater pumping over the next century. Recharge sources could include treated effluent, storm runoff from urban areas, or water brought in from other locations. LHC used the USPB groundwater model[1] to evaluate three potential near-stream recharge sites: 1) on the Babocomari River, 2) on the USPR near Garden Canyon Wash, and 3) on the USPR downstream (north) of Palominas (Figure 7).[5] Trial-and-error computer simulations were used to determine how much recharge would be required at each site in order keep baseflows from declining by the year 2100 even as groundwater depletions in the basin are expected to increase (see Figure 4). Modeling results indicate that total recharge at all three sites would have to increase from about 1,600 acre-feet per year (AF/yr) in 2012 to 3,800 AF/yr by 2100 to compensate for the effects of increased pumping as the basin's population grows. The Babocomari site would require the highest rate of recharge (up to 2,600 AF/yr by the year 2100) while the Garden Canyon Wash and Palominas-area sites would each require 500 to 700 AF/yr.[5]

Figure 7 shows how we might expect baseflows to change from March 2000 to 2050 and 2100 with recharge through shallow earthen basins at these three sites. In contrast with Figure 5, all of the stream segments downstream of the Palominas and Babocomari recharge sites show either no change (gray) or some increase (blue or green) in projected baseflow from 2000 to 2050 and 2100. Projected baseflows rise by 9% (0.1 cfs) at the Babocomari streamflow gaging station, 37% (1.6 cfs) at Charleston, and 21% (1.6 cfs) at the Tombstone gaging station. As indicated by the dark blue in Figures 5[a] and 7[a], ongoing recharge at the Sierra Vista WRF is expected to have a pronounced impact on projected downstream baseflows through 2050. By 2100 (Figure 7[b]), baseflows are still predicted to exceed 2000 levels by 15% (0.2 cfs) on the lower Babocomari, 17% (0.7 cfs) at Charleston, and 9% (0.7 cfs) at the Tombstone gaging station. Small but persistent improvements are also projected for baseflows downstream of the Palominas recharge site by 2100 under this recharge scenario.[5]

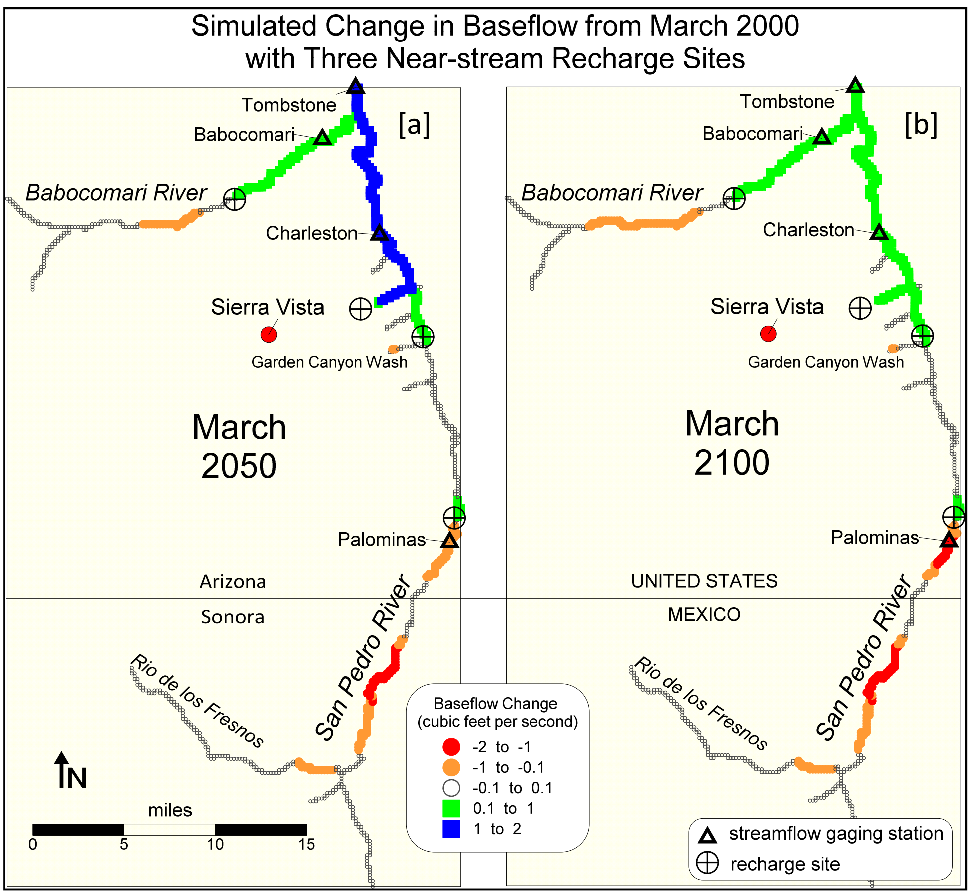

Figure 7. Simulated change in baseflow from 2000 in the San Pedro and Babocomari rivers as of: a) March 2050, and b) March 2100, with near-stream recharge implemented at three sites.

Options for the Future

If current groundwater use patterns in the USPB continue, groundwater extraction is expected to increase by more than 10,000 AF/yr (about 21%) by 2100, primarily in the urban center near Sierra Vista.[4] As a result, groundwater depletion and associated baseflow declines are expected to increase significantly by 2100. Part of a potential solution to this problem may include near-stream recharge. Groundwater model simulations suggest that increasing strategic near-stream recharge from about 1,600 AF/yr in 2012 to approximately 3,800 AF/yr by 2100 at three sites in the Sierra Vista subwatershed may sufficiently maintain groundwater levels near the river in a way that prevents pumping-related baseflow declines downstream of those sites over the next century. Determining the most appropriate sources of recharge water presents a challenge, but this study suggests that near-stream recharge can sustain baseflows near current levels in most of the Sierra Vista subwatershed even in the face of anticipated future development.

References Cited and Note

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[2] Winter, T.C., J.W. Harvey, Franke, O.L., and W.M. Alley, 1998, Ground Water and Surface Water – A Single Resource, U.S. Geological Survey Circular 1139, Denver, CO.

[3] Pool, D.R., and Dickinson, J.E., 2007, Ground-Water Flow Model of the Sierra Vista Subwatershed and Sonoran Portions of the Upper San Pedro Basin, Southeastern Arizona, United States, and Northern Sonora, Mexico: U.S. Geological Survey Scientific Investigations Report 2006-5228, 48 p.

[4] Lacher, L.J., 2011, Simulated Groundwater and Surface Water Conditions In the Upper San Pedro Basin, 1902-2105 – Preliminary Baseline Results, Task 1 Report Prepared for the Friends of the San Pedro River and the Walton Family Foundation, June, 51 p. + App.

[5] Lacher, L.J., 2012, Simulated Near-stream Recharge at Three Sites in the Sierra Vista Subbasin, Arizona, Tasks 2-4 Report Prepared for the Friends of the San Pedro River and the Walton Family Foundation, Jan., 62 p.

[a] A reduction in agricultural pumping near Palominas starting in the 1980's produces groundwater recovery in the early 2000's.

Definitions and Conversions

Acre-foot per year (AF/yr). 1 acre-foot is equal to 325,851 gallons of water and is the amount of water required to fill a 1-acre area (43,540 square feet) 1 foot deep.

Aquifer. An aquifer is a geologic formation – rocks and sediments – that contains usable groundwater. The groundwater in an aquifer is usable if it can be readily extracted with a pumping well.

Baseflow. Baseflow is the groundwater-driven component of total streamflow. If groundwater levels in the aquifer underneath a river are higher than the streambed, then groundwater will flow out of the ground and into the river, forming baseflow. Baseflow is also regarded as the flow that is independent of climate and weather, and that sustains streamflow during dry periods.

Cubic foot per second (cfs). Streamflow is commonly measured in cubic feet per second. 1 cubic foot per second equals 448.83 gallons per minute or 723.97 acre-feet per year. Baseflows in the Sierra Vista Subwatershed are typically on the order of 0 to 10 cfs.

Groundwater model. Groundwater models are computer programs that solve mathematical equations representing groundwater flow. The model described in this study uses a mathematical representation of the hydrogeology of the Upper San Pedro River basin.

Simulation. A computer simulation refers to the actual execution of the program that contains the groundwater model. A simulation is designed to represent a particular set of physical conditions in order to predict the behavior of the system under those conditions.

Streamflow Gaging Station. Streamflow may be monitored on a continuous basis by installation of a fixed set of instrumentation in the streambed. The stream gaging stations described in this study are constructed and monitored by the U.S. Geological Survey Tucson Science Center. The Palominas, Charleston, and Tombstone stream-gaging stations have long (multi-decade) periods of record, but the Lower Babocomari station dates back only to the year 2007.

Subwatershed. A watershed includes all of the contributing storm runoff area upstream of the point of that drains by overland flow to that point. The Upper San Pedro River watershed (also called the Upper San Pedro Basin) includes large areas in Sonora, Mexico and in Cochise County, Arizona. The portion of the watershed between the Mexican border and the Tombstone streamflow gaging station is referred to as the Sierra Vista subwatershed, and the area south of the border is referred to as the Sonoran subwatershed.

Prepared in Cooperation with the Friends of the San Pedro River and the Walton Family Foundation. For more information refer to the Upper San Pedro Partnership website at: *http://www.usppartnership.com/lib_study_projects.htm* and the Friends of the San Pedro River website at http://sanpedroriver.org.